EPA-PNL-2000

Glenn Suter/CI/USEPA/US	To	Jeff Frithsen, Richard Parkin, Phil North, rseal
01/07/2012 11:02 AM	cc	
	bcc	
	Subject	Fw: Comment Submittal for 2011 - 2013 Alaska Triennial Review

I just got this and have just glanced through it.
The copper industry is pushing for Alaska to adopt the EPA's BLM-based criteria.
They also make of point of streams that naturally exceed criteria as PLP does with respect to streams at the PP site on the data disk.

-----Forwarded by Glenn Suter/CI/USEPA/US on 01/07/2012 10:57AM -----
To: Glenn Suter/CI/USEPA/US@EPA
From: "Gorsuch, Joseph" <JGorsuch@cda.copper.org>
Date: 01/06/2012 04:36PM
Cc: "Gensemer, Bob" <bgensemer@geiconsultants.com>
Subject: Comment Submittal for 2011 - 2013 Alaska Triennial Review
(See attached file: ICA_AlaskaTriennialReviewReport-6Jan12.pdf)
(See attached file: ICA_CoverLetterforAK_6Jan12.pdf)

Hi Glenn: Happy New Year and best wishes for 2012!

As a follow-up to the risk assessment in the Bristol Bay Watershed that you were conducting last October, we thought you might find the attached documents just submitted to the state of Alaska for their current Triennial Review of interest. For this review, ADEC has indicated that aquatic life criteria are one of their two priority issues, and so we developed the attached report to urge ADEC to replace the hardness criteria with the BLM criteria. This is part of our ongoing efforts to urge as many states as possible to do so. We are also very active, as you know, looking at the protectiveness of copper criteria to salmonid olfactory effects, which are discussed at length in the attached submittal.

I realize that the ORD generally does not receive such comments, but still thought as a courtesy you might appreciate a copy. Contact if you have any questions or comments.

Have a great weekend.

Best regards,

Joe

Joseph W. Gorsuch

Manager, Health and Environmental Sciences

Copper Development Association Inc.

1170 Ridge Road #86

Webster, NY 14580

Tel: 585.545.4805

Fax: 866.857.3641

jgorsuch@cda.copper.org

www.copper.org

- ICA_AlaskaTriennialReviewReport-6Jan12.pdf - ICA_CoverLetterforAK_6Jan12.pdf

ALASKA TRIENNIAL REVIEW:

RECOMMENDATION TO INCORPORATE THE BIOTIC LIGAND MODEL FOR COPPER INTO AQUATIC LIFE CRITERIA

Submitted to:

Alaska Department of Environmental Conservation (ADEC)
410 Willoughby Avenue, Suite 303
P.O. Box 111800
Juneau, AK 99801-1800

Submitted by:

GEI Consultants, Inc.
Denver CO

Windward Environmental LLC
Seattle, WA

Submitted on behalf of:

Copper Development Association Inc.
New York, NY

International Copper Association, Ltd.
New York, NY

Rio Tinto
Salt Lake City, UT

January 2012

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List of Acronyms Used in This Report

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ANWR	Arctic National Wildlife Refuge
AWQC	ambient water quality criteria
BLM	Biotic Ligand Model
CDA	Copper Development Association
DOC	dissolved organic carbon
EEG	electro-encephalogram
EOG	electro-olfactogram
EPA	Environmental Protection Agency
GEI	GEI Consultants, Inc.
ICA	International Copper Association
LOECs	lowest-observed effect concentrations
NAWQA	National Water Quality Assessment
NOAA	National Oceanic and Atmospheric Administration
NOECs	no-observed effect concentrations
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
PNW	Pacific Northwest
TMDL	Total Maximum Daily Load

Executive Summary

This report provides comments as requested by the Alaska Department of Environmental Conservation (ADEC) for the current triennial review of surface water quality standards in Alaska. These comments are presented by GEI Consultants Inc. (GEI) and Windward Environmental on behalf of the Copper Development Association (CDA) and International Copper Association (ICA). The CDA is the market development, engineering, and information services arm of the copper industry. The CDA and ICA played a significant role in sponsoring scientific research used in development of the freshwater Biotic Ligand Model (BLM) for copper. In early 2007, the Environmental Protection Agency (EPA) released revised national aquatic life ambient water quality criteria for copper in freshwater, which are based on the BLM (EPA 2007a). Since EPA published the BLM-based criteria, further evaluations have shown the BLM is also appropriately protective against olfactory impairment in juvenile salmon. Given the opportunity and main goal of triennial reviews, the CDA and ICA encourage states and tribes to incorporate these latest recommended EPA national criteria for copper into their water quality standards programs.

It is our understanding that Alaska has initiated the triennial review process and that you are currently accepting written comments, which are due by January 6, 2012. The purpose of this report is to urge ADEC to consider updating its aquatic life criteria for copper by allowing the use of the BLM, as recommended by the EPA. This proposal outlines our rationale, the technical basis for the BLM, recommendations with respect to application of the BLM criteria, and proposed changes to Alaska's freshwater aquatic life standards for copper.

1.0 Introduction

The current Alaska water quality standards include aquatic life water quality criteria for metals that have not been updated for many years, in some cases more than two decades. These criteria include the priority pollutant metals arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. In the period since Alaska last updated their aquatic life criteria, the EPA, other states, and various organizations have updated criteria for many of these metals and other non-priority pollutant metals, such as aluminum. These updates encompass more current scientific information and have used the EPA procedures for updating criteria, and in many cases are already EPA-approved. It is the EPA's policy to update criteria as new scientific information becomes available, especially that which could significantly affect environmental management decisions. Therefore, these updates give Alaska an opportunity to bring their state water quality standards up-to-date and provide more appropriate policy and more accurate tools for regulating and managing water quality.

The Alaska water quality standards contain the aquatic life criteria for copper in the 2008 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances (ADEC 2008). The current Alaska acute and chronic copper criteria are calculated as a function of water hardness and are based on the 1995 EPA Updates (EPA 1996). However, basing copper criteria on hardness is a scientifically outdated approach. Instead, the more mechanistically appropriate Biotic Ligand Model (BLM) is the most current and scientifically rigorous basis for establishing freshwater copper criteria, as recommended by the EPA in their most current national recommended water quality criteria (EPA 2007a). The BLM represents a significant step forward in the best available science of copper toxicity and derivation of criteria that are appropriately protective of freshwater organisms, including olfactory effects in juvenile salmon (Meyer and Adams 2010, DeForest et al. 2011). Nine states have adopted the EPA's BLM-based copper criteria in their water quality standards, but to-date, most have adopted the BLM as a tool for deriving site-specific standards rather than as the default basis for copper criteria incorporated into water quality standards statewide.

The BLM generates instantaneous criteria (acute and chronic) using 10 water quality input parameters that typically cost less than $200 per sample. These 10 input parameters are: temperature, pH, and concentrations of dissolved organic carbon (DOC), calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity. The BLM software is publicly available, sanctioned by EPA, and requires only brief training to generate rapid and useable output.

Alaska's current aquatic life copper criteria, like most states' criteria, only take into account hardness as a factor that modifies toxicity. Using only hardness as a modifying factor for metals criteria is an outdated approach that does not take into account a substantial body of science. The peer-reviewed scientific literature demonstrates that additional modifying factors can and should be incorporated into regulatory benchmarks or standards, while providing the same level of aquatic life protection (EPA 1985, 1994, 2001, 2007a). Copper toxicity is a function of its bioavailability, which in addition to being controlled by hardness, is also strongly related to other important factors such as DOC, alkalinity, pH, and temperature. The key strength of the BLM is that it accounts for multiple factors—in addition to hardness—that influence the amount of copper that is bioavailable to aquatic life and, hence, potentially toxic. Therefore, the BLM-based criteria can provide more accurate levels of aquatic life protection across a broad range of water quality conditions than the outdated hardness-based criteria.

In Alaska, there are well over a thousand National Pollutant Discharge Elimination System (NPDES) permittees subject to compliance based on the outdated 1995 EPA copper criteria. NPDES permits are the principal regulatory vehicle for Clean Water Act implementation to protect and restore water quality. NPDES permits rely on state water quality standards and criteria for setting appropriate compliance levels. Water quality criteria drive permit compliance decisions and can lead to significant capital expenditures. Water quality criteria also drive the 303(d) and TMDL process for identifying and cleaning up impaired water bodies. Using outdated criteria for NPDES, 303(d), and TMDL purposes could lead to resources being wasted on unnecessary listings (i.e., false positives). Using outdated criteria may also result in under-protection of aquatic life (i.e., false negatives). Therefore, Alaska should consider adopting the most current EPA criteria for protection of freshwater aquatic life, which for copper are the 2007 BLM-based criteria.

2.0 Technical Basis of the Copper BLM

The copper BLM is a computational model that incorporates chemical reaction equations to evaluate the amount of metal that would bind to organism tissues (termed the "biotic ligand", such as a fish gill) and thus be ultimately responsible for causing toxicity. By incorporating chemical equilibria, the BLM better represents the complex chemical factors that influence copper bioavailability, more so than the simple hardness-based approach (Di Toro et al. 2001; De Schamphelaere and Janssen 2002). Unlike the hardness-based equation for copper criteria, the BLM explicitly accounts for more of the important water quality variables that determine bioavailability, and the BLM is not limited to a statistical correlation that lacks a mechanistic underpinning between toxicity and these variables.

The mechanistic principles underlying the BLM follow general trends of copper toxicity as related to individual water quality variables and their combinations. The basic premise of the BLM is that changes in water quality will cause a corresponding change in bioavailability, estimated as the amount of metal that will bind to biological surfaces (i.e., the "biotic ligand"; Di Toro et al. 2001; EPA 2007a). For example, increases in pH, alkalinity, or natural organic matter all tend to decrease copper bioavailability to varying degrees and hence decrease toxicity, which results in increased dissolved copper toxicity thresholds derived on the basis of both acute and chronic endpoints, including olfactory impairment (Erickson et al. 1996; Di Toro et al. 2001; De Schamphelaere and Janssen 2004; McIntyre et al. 2008).

Copper bioavailability is also affected by competitive chemical binding interactions at the biotic ligand (e.g., fish gill) with calcium, magnesium, and sodium, which are important for metabolic and ion regulatory activities in the gill, thereby reducing toxicity (i.e., increasing dissolved copper toxicity values; Erickson et al. 1996; Di Toro et al. 2001; De Schamphelaere and Janssen 2004). The interactions between the biotic ligand (e.g., the fish gill) are shown in Figure 1. Each of the dissolved chemical species with which the biotic ligand reacts is represented by characteristic binding site densities and conditional stability constants (Playle et al. 1993). In turn, each of the chemical species can be predicted as a function of inorganic and organic equilibrium reactions. The thermodynamic constants used to simulate these equilibrium reactions are empirically derived and do not change for simulations involving different organisms.

Predictions of acute or chronic copper toxicity are based on the relationships between the dissolved copper toxicity threshold and a critical level of copper accumulation at the biotic ligand. In an acute context, this critical accumulation is called the median-lethal biotic ligand accumulation concentration, or LA_{50} (analogous chronic critical accumulation concentrations can be derived). While LA_{50} values can vary based on differential species sensitivity (i.e., more or less copper-gill accumulation required to exert a similar toxic response), they are assumed to be constant within individual species, regardless of water quality (Meyer et al. 1999). For example, although binding constants for copper and other cations were derived using fathead minnows, the binding constants apply equally well to invertebrates and other fish (Santore et al. 2001). The only difference among the species is their LA_{50}s.

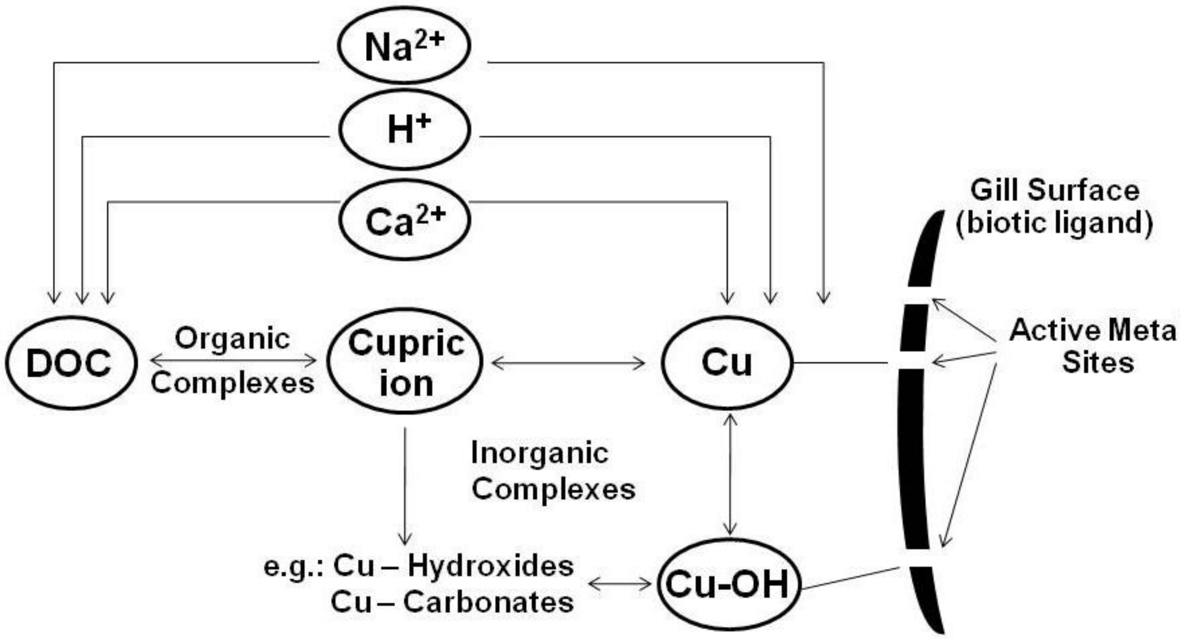

Figure 1: Conceptual diagram of the Biotic Ligand Model for copper. Source: Adapted from EPA (2007a).

The BLM-based copper criteria were ultimately developed using an approach that is analogous to EPA metals criteria derivation methods that are based on normalizing available toxicity data to a similar hardness (EPA 1985). In the 2007 recommended water quality criteria (EPA 2007a), the BLM was used to normalize LC_{50} values to a single reference exposure condition that includes all of the water quality parameters included in the BLM. Although not all historical studies reported concentrations of parameters needed for the BLM, the dataset was supplemented by new data from current research. After the data were normalized to the BLM parameters for this reference exposure condition, criteria derivation procedures followed EPA guidance (EPA 1985). Accordingly, the acute criterion was estimated from a ranked distribution of BLM-normalized genus-mean acute values from which the 5^{th} percentile of sensitivity (i.e., the Final Acute Value) was divided by two to calculate the acute criterion. Insufficient data were available to explicitly derive a separate BLM-based chronic criterion. Thus, according to EPA guidance, the BLM-normalized acute criterion was divided by the Final Acute-Chronic Ratio to derive a chronic criterion (EPA 2007a). Therefore, nothing will be changed in the criteria-derivation process except the

LC_{50}-normalization step, which now will replace the old normalization model (the hardness-adjustment equation) with the new normalization model (the BLM).

Use of the BLM represents a significant improvement upon the current hardness-based copper criteria. The BLM has been adequately validated for a wide range of water quality conditions, and therefore provides more accurate and scientifically-defensible water quality criteria. Validation studies have shown that over a very wide range of water quality characteristics (e.g., hardness, alkalinity, and ion composition), the BLM provides criteria concentrations that are more accurate and consistently protective of even the most acutely sensitive aquatic organisms (Gensemer et al. 2002; Van Genderen et al. 2007), including protection against olfactory impairment in fish, as discussed further in Section 3 below.

3.0 Protection Against Olfactory Impairment in Fish

In ADEC's document: *Water Quality Standards Current Issues, November 2011* that accompanies the public announcement of the Triennial Review, concerns appear to be focused on the extent to which aquatic life criteria for copper would be protective of sensory or olfactory effects. Specifically, it was stated that "copper affects the salmonid olfactory system at lower concentrations [than the acute or chronic criteria], which may affect their survival or reproduction." However, recent publications suggest BLM-based criteria would be protective against olfactory impairments in fish, even more so than current hardness-based criteria. These publications are discussed further in this section below, and are appended to this report for your reference.

Recent studies by the National Oceanic and Atmospheric Administration (NOAA) and others have demonstrated that short-term laboratory exposures to low copper concentrations (e.g., <20 µg/L) in synthetic laboratory waters can cause olfactory impairment in fish, which may limit the ability of fish to detect and avoid predators (e.g., Hansen et al. 1999; McIntyre et al. 2008; Green et al. 2010). The ability of low copper concentrations to result in olfactory impairment is of particular concern in the Pacific Northwest (PNW) region of the United States due to the presence of Pacific salmon (*Oncorhynchus* spp.), many populations of which are listed as threatened or endangered under the Endangered Species Act. Some recent papers, such as McIntyre et al. (2008), suggest that existing copper criteria may not be protective against olfactory impairment in juvenile salmon. However, as discussed below, this position does not appear to be supported, particularly when considering BLM-based copper criteria. Further, the McIntyre et al. (2008) results are based upon testing with juvenile fish in the laboratory and extrapolated to adult fish returning during a spawning run in natural streams.

The EPA's ambient water quality criteria for protection of aquatic life are derived primarily using endpoints of survival for acute criteria and survival, growth, and reproduction for chronic criteria. However, other sub-lethal endpoints can be considered if they are ecologically important or can be reliably linked to these traditional acute or chronic criteria endpoints. Therefore, the copper concentrations shown to result in olfactory impairment in juvenile salmon and other fish should be compared to both the acute and chronic hardness- or BLM-based copper criteria.

Based on these comparisons, new studies indicate that the BLM-based copper criteria (EPA 2007a) would be protective of olfactory impairment, while hardness-based copper criteria are usually, but not always, protective across a broad range of water quality conditions representative of the PNW (Meyer and Adams 2010; DeForest et al. 2011). The protectiveness of the BLM-based copper criteria, and to a lesser degree the hardness-based criteria, is largely because of the greater sensitivity of some invertebrates to copper relative to fish. In other words, although olfactory impairment resulting from short-term copper exposures can be a more sensitive endpoint in fish than lethality, the greater sensitivity of invertebrates ultimately results in copper criteria that are protective of olfactory impairment in fish.

Meyer and Adams (2010) compiled copper studies that evaluated olfactory impairment, based either on electro-encephalogram (EEG) or electro-olfactogram (EOG) responses to a natural odorant, or avoidance behavior, and where sufficient water chemistry data were available to derive BLM-based copper criteria. IC_{20} values (20% impairment concentrations) were calculated for olfactory impairment and avoidance in 16 different tests encompassing varying water chemistry and test species, including those conducted by McIntyre et al. (2008). Meyer and Adams (2010) concluded that chronic BLM-based copper criteria were protective of the olfactory response and avoidance IC_{20} values in all 16 waters and acute BLM-based criteria were protective in all but two waters. Meyer and Adams (2010) also parameterized an olfactory-based BLM that can be used to estimate olfactory-based copper IC_{20} values for waters with varying chemistry. In turn, DeForest et al. (2011) used the olfactory-based BLM to estimate copper IC_{20} values for olfactory impairment based on water chemistry data sets for 133 western United States streams. In this work, the olfactory BLM-based copper criteria were always less than the predicted IC_{20} values for olfactory impairment, while the hardness-based criteria exceeded the IC_{20} values in some cases (Figure 2). These results demonstrate that the BLM-based criteria are more consistently protective against olfactory impairment than the hardness-based criteria that are currently used in Alaska. Furthermore, these studies show that the BLM can be adapted to endpoints other than the conventional acute and chronic criteria basis, which in this case is the olfactory response.

Therefore, the BLM-based aquatic life criteria for copper are the most accurate regulatory tools for ensuring adequate levels of protection for fish against olfactory effects. In contrast, it appears that the current hardness-based aquatic life criteria would not consistently provide adequate protection against potential olfactory effects. This situation means that continued use of hardness-based copper criteria in Alaska surface waters could present reduced levels of protection for sensitive salmonid populations. The BLM-based copper criteria, therefore, present a means to more adequately regulate and manage water quality because they encompass current science and endpoints of regional significance.

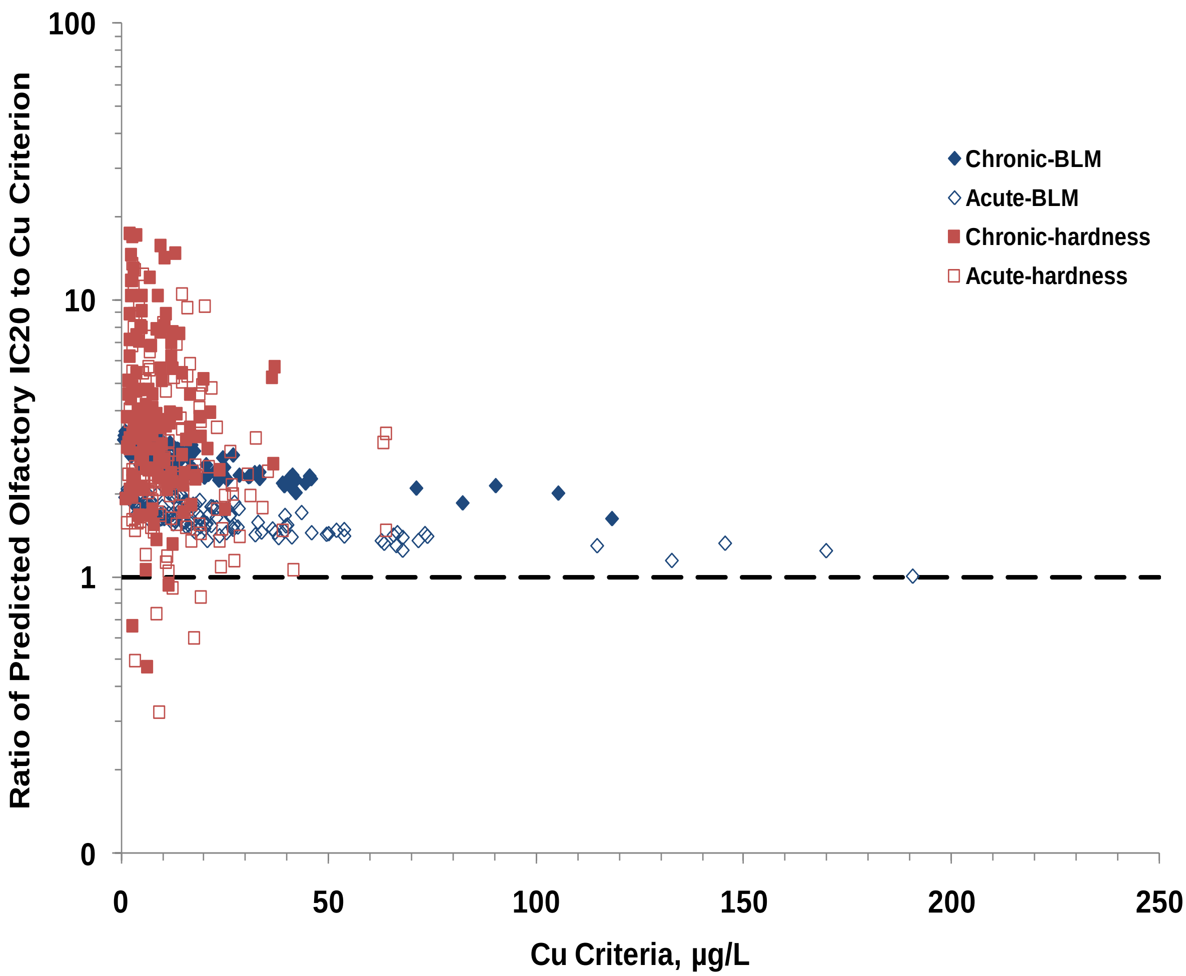

Figure 2: Ratios of predicted olfactory IC_{20} values to BLM- and hardness-based Cu criteria as a function of Cu concentrations. Source: Adapted from DeForest et al. (2011).

3.1 Olfactory Protection in Saltwater Fish

The above overview provides evidence to support that the data available to date support that the BLM-based copper ambient water quality criteria (AWQC) for freshwater are protective against olfactory impairment in freshwater life stages of juvenile salmon. Although the effects of copper on olfactory function in saltwater fish or saltwater life stages of salmon have not been studied, there are data demonstrating that major ions (Ca^{2+}, Mg^{2+}, Na^{+}) and amino acids elicit a similar olfactory response in freshwater-adapted and saltwater-adapted rainbow trout (*Oncorhynchus mykiss*) (Shoji et al. 1996). Based on these data, it is hypothesized that an olfactory-based copper BLM applicable to both freshwater and saltwater fish could be parameterized. Preliminary evaluations indicate that this re-parameterized olfactory-based copper BLM improves the predictability of olfactory impairment thresholds (i.e., IC_{20} values) when applied to the juvenile coho salmon data from McIntyre et al. (2008). If the hypothesis holds that the re-parameterized olfactory-based copper BLM provides accurate predictions of olfactory impairment in saltwater fish, it is expected that saltwater BLM-based copper criteria will also protect against olfactory impairment in saltwater fish. For example, in full strength seawater with a pH of 8.0 and salinity of 30‰, the draft BLM-based copper criteria are 1.6, 16.8, and 40 µg/L at DOC concentrations of 0.3, 3.1, and 7.4 mg/L, respectively. For comparison, in typical seawater with a salinity of 30‰ at the same DOC concentrations, the predicted IC_{20} values for olfactory impairment are 13, 52, and 111 µg/L, respectively (or approximately 2.8 to 8.1 times greater than the draft BLM-based criteria). In freshwater, the magnitude of copper AWQC are driven by sensitive invertebrates, such as cladocerans, which helps ensure protection against olfactory-related effects in freshwater fish. In saltwater, the draft copper AWQC are likewise driven by a sensitive invertebrate, *Mytilus* spp., which may also provide the necessary protection against any chronic endpoint for fish, including olfactory impairment.

It is important to note that for both freshwater and saltwater, water chemistry strongly influences copper bioavailability and hence toxicity. Therefore, it is imperative to know the water chemistry in which copper toxicity tests were conducted in order to determine whether copper criteria are protective of a given species and endpoint (e.g., olfactory impairment in salmon). The low olfactory-impairment concentrations of 1-2 µg Cu/L that have been reported for laboratory waters containing low hardness, low alkalinity, and low DOC concentrations are far too conservative and have no relevance in most natural waters (especially in waters containing greater than 0.1 mg DOC/L). Instead of defaulting to the lowest concentration that has caused olfactory impairment regardless of water chemistry, the copper BLM is by far the most robust tool for ensuring that criteria meet the desired level of aquatic community protection.

3.2 Protection of Fish Behaviors Related to Olfactory Impacts

Freshwater and saltwater fish behavior studies have also been recently reviewed and compared to existing regulatory criteria for copper (Shephard and Zodrow 2009). Those authors identified behavioral studies following the definition of Henry and Atchison (1991), who defined behavior as “the organismal level manifestation of the motivational, biochemical, physiological, and environmentally influenced state of the organism.” Shephard and Zodrow (2009) only considered organism-level endpoints in their review and, therefore, excluded suborganismal endpoints, such as studies that directly tested the effects of Cu on the primary sensory neurons of the olfactory epithelium. In their review, lowest-observed effect concentrations (LOECs) and no-observed effect concentrations (NOECs) were compiled from laboratory studies using copper alone, as part of mixtures, and from field behavioral studies. Of the 147 available LOEC values for laboratory studies with copper in freshwater, all but three were higher than the existing hardness-based chronic copper criterion—indicating that for the most part, fish behavior will not be adversely affected if the copper concentration does not exceed the criterion (Shephard and Zodrow 2009; Burt

Shephard, EPA, personal communication). Avoidance behavior was the most commonly studied behavioral endpoint, and is the only behavioral endpoint with LOECs lower than the chronic copper criterion. None of the 20 laboratory LOEC values for marine fish exposed to copper alone were lower than the EPA's current marine chronic criterion of 3.1 µg Cu/L (Shephard and Zodrow 2009; Burt Shephard, EPA, personal communication).

Overall, the evidence indicates that BLM-based Cu criteria are protective of olfactory impairment and related behaviors in fish, but this has primarily been evaluated for freshwater fish or using freshwater life stages of anadromous fish. By comparison to freshwater organisms, far fewer olfactory or behavioral studies have been conducted with saltwater fish or invertebrates. Furthermore, with the exception of the behavioral review by Shephard and Zodrow (2009), no comparisons of olfactory or other related sublethal effects have been made to saltwater aquatic life criteria for copper.

4.0 Application of the BLM to Water Quality Criteria

It is important to note that both the hardness-based and BLM-based freshwater copper criteria rely on "models" to calculate criteria. For hardness-based metals criteria, a simple equation, which is in essence a "model," mathematically relates the criterion concentration to a single variable, in this case hardness (hardness is an aggregate measure of the concentrations of the calcium and magnesium cations). For the BLM-based copper criteria, a mechanistic computer model mathematically relates multiple water quality characteristics, including hardness cations, to the final criterion concentration. Hence, the National Criteria Statement in the 2007 criteria document (EPA 2007a) is as follows:

The available toxicity data, when evaluated using the procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that freshwater aquatic life should be protected if the 24-hour average and four-day average concentrations do not respectively exceed the acute and chronic criteria concentrations calculated by the Biotic Ligand Model.

Like any policy, changes to a regulatory criterion should consider implementation needs and how they will be different from the status quo. Most states have guidance documents for implementing water quality criteria, which can be a more appropriate place to provide the necessary details for implementation than the water quality standards language, especially given that rulemaking considerations affect only the standards. Accordingly, ADEC should thoroughly evaluate their related guidance and policy documents so they are effective and up-to-date with best practices and EPA guidance.

For determining copper criteria under either approach, measurements of Ca^{2+} and Mg^{2+} are needed (assuming the hardness-based criterion would employ the more accurate method for determining hardness by calculating hardness from the Ca and Mg ion concentrations per SM2340B). Therefore, the difference between data needs for the hardness-based and BLM-based criteria are the remaining eight BLM parameters: temperature, pH, alkalinity, DOC, Na^+, K^+, Cl^-, and SO_4^-. Temperature and pH data must be field collected, which is a straight-forward process using handheld meters or simpler means. For the remaining additional parameters, the costs for analyses by accredited laboratories are typically less than $100. Furthermore, samples for these analyses are as easily collected as the samples for hardness-based criteria. Note that DOC samples must be filtered shortly after collection, which is also needed for evaluating metals criteria compliance based on a dissolved (filtered) metals sample. Therefore, the added cost and field effort for BLM data needs are minimal.

It should be noted that approaches are being developed that may greatly simplify data collection needs and costs for deriving and implementing BLM-based criteria. These approaches consider that not all 10 BLM parameters are equally sensitive to deriving criteria concentrations, and some parameter concentrations can be estimated from others recognizing that many water quality parameters are correlated with one another. For example, one approach being considered is to estimate concentrations of other inorganic ions from calcium concentrations, or to use broad geographic “default” values to derive BLM-based criteria (Peters et al. 2011). That study suggested that while fixed defaults were appropriately conservative, estimating ion concentrations from calcium was more accurately predictive of BLM criteria derived from all 10 parameters. Similarly, HydroQual (2008) suggested that using central tendency estimates of ion concentrations for all parameters except pH and DOC were adequate for derivation of BLM-based criteria.

The next criteria implementation need would address the number and location of water quality samples that need to be collected to adequately characterize a particular water body for applying the criterion. General guidance is available from EPA which provides several suggested sampling strategies depending on the type of water body and the anticipated seasonal or spatial variation anticipated in BLM parameters (EPA 2007b). This potential issue of variability over time and space would be important to address for both the BLM and the current hardness-based criterion. It is important to note that any criterion based on an instantaneous or short-term measurement of a water quality variable such as hardness would be susceptible to certain time-variability considerations. Therefore, this situation is not unique to the BLM (EPA 2007a):

With regard to BLM-derived freshwater criteria, to develop a site-specific criterion for a stream reach, one is faced with determining what single criterion is appropriate even though a BLM criterion calculated for the event corresponding to the input water chemistry conditions will be time-variable. This is not a new problem unique to the BLM—hardness-dependent metals criteria are also time-variable values. Although the variability of hardness over time can be characterized, EPA has not provided guidance on how to calculate site-specific criteria considering this variability. Multiple input parameters for the BLM could complicate the calculation of site-specific criteria because of their combined effects on variability. Another problem arises from potential scarcity of data from small stream reaches with small dischargers.

Depending on the geochemistry of a particular water body, only a few sets of water quality data may need to be collected throughout a season to adequately characterize conditions of lowest vs. highest copper bioavailability. For example, Verschoor et al. (2011) suggested it may not be necessary to collect more than 3-4 sets of water quality data to fully characterize seasonal variation, as demonstrated for chronic BLM copper criteria in Europe. We suggest that it would be most important to characterize times of year with the lowest vs. highest DOC concentrations and pH, and secondarily, hardness cations and alkalinity because these will have the most significant impact on BLM criteria calculations. For example in streams, these are likely to be related to times of year with the lowest vs. highest stream flow conditions.

EPA has also provided general guidance as to the various regulatory options that could be used to encourage states and tribes to implement BLM-based copper criteria in their water quality standards programs (EPA 2007c). This guidance emphasizes that considerable flexibility exists in implementing BLM-based copper criteria, with suggested implementation options being full statewide implementation of the BLM-based criteria, or the incremental approach of using the BLM for certain water bodies (i.e., Total Maximum Daily Load [TMDLs]) on a site-specific basis. These two options outlined in EPA's general implementation guidance (EPA 2007c) are briefly summarized below:

1. Full Statewide Implementation

Under this approach, a state would implement the BLM-based criteria as a full replacement of the hardness-based criteria. In Alaska, the hardness-based criteria equations for copper referenced in the table and appendix of ADEC (2008) would be deleted and replaced with text citing the EPA 2007 criteria document. In addition, a lookup table could be created for a defined set of water chemistries for those who might not want or need to use the model for a particular discharge or location. This approach would allow a state to use the BLM as a statewide standard. The new numeric criteria derived using the BLM would most likely begin to apply as new permits and TMDLs are developed or existing permits are renewed. This implementation approach would depend on the availability of sufficient water quality data for the 10 BLM input parameters in the waterbodies for which the new standards would apply (although it may be possible to simplify input data needs as discussed above). To date, no state has fully replaced their hardness-based copper criteria with BLM-based criteria. Only one state (South Carolina) has adopted the BLM as an alternative to the hardness-based criteria for derivation of water quality criteria, but still stopped short of full statewide implementation.

2. Incremental Implementation

A more incremental and practical approach would enable states and tribes to move as quickly as possible to adopt the BLM methods into water quality standards by allowing use of BLM-based copper criteria on a site-specific basis. Under this approach, the hardness-based criteria would continue to be the "default" basis of copper standards, except in waters where site-specific criteria are eventually derived using the BLM. EPA suggests that some of the higher priority sites for development of BLM-based criteria might be those waters in which hardness-based standards are likely to be significantly over-protective (e.g., waters with high concentrations of dissolved organic carbon) or significantly under-protective (e.g., waters with low pH or alkalinity). Thus, this approach would allow for the most rapid and efficient implementation of BLM-based criteria by focusing on water bodies in which they would have the most impact, and providing additional time and resources to collect the necessary data for full statewide implementation. Eight states currently allow use of the BLM as a site-specific criteria derivation tool (Maryland, Missouri, New Hampshire, New Jersey, New Mexico, North Carolina, Pennsylvania, and Texas).

5.0 Review of Copper Concentrations, Copper Criteria, and Salmon Return Data for Alaskan Streams

There is a question as to whether or not several Alaska streams have high copper concentrations relative to other regions, yet support strong Pacific salmon populations. As a case-in-point, the Copper River is presumed to have elevated copper concentrations, yet boasts one of the most highly regarded salmon fisheries in Alaska. To evaluate whether this perception is indeed true, we recently evaluated the extent with which copper concentrations in Alaskan streams exceed hardness- and BLM-based copper criteria, as well as BLM-predicted IC_{20} values for olfactory impairment following the method of Meyer and Adams (2010), discussed above. We then compared these results to existing salmon return data in order to evaluate whether there were any correlations with the magnitudes of copper concentrations in Alaska streams.

The copper concentrations and other water chemistry data (e.g., hardness, pH, DOC, etc.) were compiled from publically available on-line databases (the U.S. Geological Survey's Water-Quality Assessment [NAWQA] Program database and National Water Information System [NWIS] database). In addition, chemistry data for the Copper River and several of its tributaries were compiled from a State of Alaska Department of Natural Resources report (Maurer and Ray 1992) because data for these water bodies were not available in either of the USGS databases. Finally, for stream locations where copper concentrations exceeded copper criteria, salmon population data were gathered from the Alaska Department of Fish and Game (ADF&G) website (ADF&G 2011).

Based on the data compiled, we found that very few Alaskan streams had copper concentrations exceeding criteria. Of the 453 samples compiled for this evaluation with sufficient information to derive BLM-based copper criteria, only 19 samples had at least one copper concentration exceeding the acute criterion (4%, nine streams) and 33 samples had at least one copper concentration exceeding the chronic criterion (7%, 11 streams). A similar pattern was observed for the hardness-based copper criteria. Finally, with one exception, none of the stream samples had a copper concentration greater than the predicted olfactory-based IC_{20} value, as derived using the method of Meyer and Adams (2010). The one exception was Hue Creek (located in the Arctic National Wildlife Refuge [ANWR]), which had a dissolved copper concentration of 4 µg/L and the predicted olfactory-based IC_{20} value was 3.9 µg/L, which are essentially equivalent. Overall, therefore, the Alaskan streams, for which copper data are available, do not have copper concentrations exceeding BLM-based criteria or predicted olfactory-based toxicity thresholds for salmon.

Given the spatial and temporal variability in the copper concentration data relative to the salmon population data, correlations between the two are tenuous. The salmon population data were typically available at a much larger spatial scale, with trends expressed over several years (or decades), while copper concentration data were often only available for a select location on a stream and for a limited number of years. In addition, as noted above, very few Alaska streams had copper concentrations exceeding criteria. Accordingly, there were limited opportunities to co-locate streams with copper criteria exceedances with salmon population data. Additionally, the influence of harvest rates and hatchery stocking rates, which vary between years, further compounds the uncertainties in this evaluation. However, copper criteria exceedances were so infrequent, and negligible in magnitude, that any reductions in a salmon fishery for a given region would almost certainly be attributed to other factors (e.g., harvest rates, hatchery production). The potential contribution of copper to any decline is clearly uncertain.

Despite the above uncertainties, there is no evidence to suggest that existing copper criteria, whether BLM-based or hardness-based, are under-protective of salmon. For example, in the Hue Creek example noted above, which is located within ANWR, there are no fish surveys available, but the larger management area that comprises Hue Creek is known to support subsistence fisheries of several salmon species (ADF&G 2011). In fact, the slight exceedance of a BLM-based copper criterion at a stream site within ANWR seems to support that the criterion is not under-conservative and may actually be over-conservative, at least for some sites. Similarly, the Kenai River, which had a copper concentration from a single sample collected near Sterling in 1999 exceeding the acute copper criterion, supports a significant salmon fishery, with sockeye salmon returns exceeding forecasts in recent years (ADF&G 2011). These types of observations, along with the finding that copper concentrations throughout the state are less than predicted olfactory-based IC_{20} values for salmon, suggest that existing streams with copper concentrations meeting copper criteria are protective of salmon, with some examples suggesting that certain streams can tolerate copper concentrations that moderately exceed criteria, at least at times, without any clear effect on salmon populations.

Finally, although copper concentrations in the Copper River, famous for the strength of its salmon runs, may not be as high as sometimes perceived, the Copper River still provides support that existing copper criteria are protective of salmon and do not need to be lowered. For example, long-term historical copper concentrations in the main stem of the Copper River ranged from <1 to 23 µg/L from the 1950s through 1991, with certain tributaries similarly having copper concentrations of approximately 10 µg/L (Maurer and Ray 1992). Given that the hardness of the main stem of the Copper River ranges from moderately-hard to hard, these copper concentrations appear to variably be near associated hardness-based copper criteria (i.e., sometimes below and sometimes above). This again provides some support that the existing copper criteria are at least protective against effects on salmon. The detailed methods and results of this evaluation are provided in Appendix A to these comments.

6.0 Proposed Changes to ADEC 2008

GEI, CDA, ICA, and Windward Environmental encourage ADEC to consider using the BLM as an alternative to the hardness-based approach for deriving copper water quality criteria in ADEC (2008). Use of the BLM to derive copper water quality criteria is based on the most current science and is recommended by the EPA (EPA 2007a). The costs for additional data needs and sampling effort are minimal compared with current approaches needed for hardness-based criteria. The most scientifically rigorous approach would be full statewide implementation of BLM-based criteria for copper. This approach would allow Alaska to use the latest available science to derive new or revised water quality standards that are more consistently protective against the effects of copper on aquatic life, including olfactory impairment in juvenile salmon, in all surface waters in Alaska.

Due to the BLM's increased precision and efficiency compared to the hardness-based criteria, cost effectiveness, availability to the public and technical simplicity, we recommend use of the BLM to calculate copper criteria in Alaska. We also recognize that it may be more practical to implement BLM-based criteria on a more incremental or site-specific basis until sufficient water quality data are available for derivation of statewide criteria. This would also allow ADEC to apply the BLM to waters for which the hardness-based criteria are most likely to be over- or under-protective of aquatic life.

We appreciate the opportunity to provide you these comments. Please let us know if you have any questions. We look forward to discussing this with you further.

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Appendix A

Technical Memorandum: Evaluation of Copper Concentrations and Criteria in Alaska Streams Relative to Pacific Salmon Population Data

4601 Denver Tech Center Blvd. • Suite 900
Denver, CO 80237
Phone: 303.264.1084
www.geiconsultants.com

200 West Mercer St. • Suite 401
Seattle, WA 98119
Phone: 206.812.5426
www.windwardenv.com

TECHNICAL MEMORANDUM

To: Bill Adams, Ph.D. (Rio Tinto)
Joe Gorsuch (Copper Development Association)

From: Carrie Claytor (GEI Consultants)
David DeForest (Windward Environmental)

Subject: Evaluation of Copper Concentrations and Criteria in Alaska Streams Relative to Pacific Salmon Population Data

Date: August 29, 2011

BACKGROUND

In 2010 an initial evaluation of copper (Cu) concentrations in Alaska streams relative to biotic ligand model (BLM)-based Cu criteria was conducted. The overall objective was to identify whether there are Alaska streams with relatively high Cu concentrations that support healthy Pacific salmon populations. Overall, a limited number of streams were identified with Cu concentrations exceeding criteria. Nevertheless, based on subsequent conversations with other team members working on the Cu-olfactory issue, it was suggested that it would still be beneficial to take the effort a step further and evaluate whether salmon population data are available for streams where Cu concentrations have been measured. This would provide the opportunity to not only evaluate whether there are streams with healthy salmon populations and Cu concentrations exceeding criteria, but also an opportunity to demonstrate that existing Cu criteria are adequately protective of salmon (providing further support that existing Cu criteria do not need to be lowered to protect against olfactory impairment).

INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) recommends ambient water quality criteria (AWQC) for the protection of aquatic life and their uses (USEPA 1985). The USEPA's recommended AWQC provide guidance for states or tribes in developing numeric criteria that are then incorporated into their water quality standards (WQS) to ensure protection of designated uses. The numeric Cu criteria adopted by the State of Alaska (ADEC 2008) are adjusted for site-specific hardness based on the USEPA's 1995 AWQC updates (USEPA 1996).

The hardness-based Cu criteria increase with increasing hardness because calcium and magnesium ions compete with Cu for uptake by aquatic biota. Because water chemistry parameters in addition to hardness also strongly influence Cu bioavailability, such as dissolved organic carbon (DOC), pH, and alkalinity, the USEPA has recently recommended Cu criteria that are derived using the biotic ligand model (BLM; USEPA 2007). The BLM derives AWQC as a function of several water chemistry parameters, including temperature, pH, alkalinity, DOC, and multiple ions, including calcium, magnesium, sodium, potassium, sulfate, and chloride (USEPA 2007). However, to-date, BLM-based numeric criteria for Cu have not been incorporated into the WQS for Alaska or other states.

Recently, several studies have demonstrated that short-term exposures to Cu can result in olfactory impairment in juvenile Pacific salmon (*Oncorhynchus* spp.) at concentrations less than those required to cause acute mortality in juvenile salmon (Baldwin et al. 2003; 2011; Sandahl et al. 2004, 2006, 2007; McIntyre et al. 2008a). Olfactory impairment is a significant effect because it could reduce the ability of juvenile salmon to avoid predators, as well as interfere with the ability of salmon to recognize kin, synchronize reproduction, and return to their natal stream to spawn (Baldwin et al. 2003). Meyer and Adams (2010) demonstrated that existing hardness- and BLM-based Cu criteria are protective against both olfactory impairment and behavioral avoidance in juvenile salmonids, based on the toxicity data available to-date. Further, Meyer and Adams (2010) re-parameterized the BLM such that the IC20 for olfactory impairment can be predicted over a range of water chemistries (i.e., varying DOC, pH, etc.). DeForest et al. (2011) then applied the olfactory-based BLM to 133 stream sites in western U.S., including Alaska, and found that the acute and chronic hardness-based Cu criteria were less than (i.e., protective of) the predicted IC20s for olfactory impairment in 122 (92%) and 129 (97%) of the stream sites, respectively, and the BLM-based criteria were always protective. The overall protectiveness of the existing Cu criteria is attributed to the sensitivity of several invertebrate species, which are several-fold more sensitive than salmonids (USEPA 2007).

Several Alaska streams are perceived to have relatively high Cu concentrations relative to other regions, yet support strong Pacific salmon populations. As a case-in-point, the Copper River is presumed to have elevated copper concentrations, yet boasts one of the most highly regarded salmon fisheries in Alaska. An 1888 New York Times article, for example, provided a first-hand account on the prevalence of copper in the Copper River watershed, such as the Chittyto, a tributary to the Copper River, where a deep yellow color was observed. Thus, the overall objective of this evaluation was to use salmon population and Cu concentration data for Alaska streams to determine whether these field data can be used to make conclusions on the protectiveness of Cu criteria on salmon populations.

METHODS

Stream Data Collection

Alaska stream water quality data were compiled from the US Geological Survey's Water-Quality Assessment (NAWQA) Program database (http://water.usgs.gov/nawqa/) and National Water Information System (NWIS) database (http://waterdata.usgs.gov/nwis). Duplicate data reported in both the NAWQA and NWIS databases were removed. The data were filtered to identify all samples where Cu concentrations were measured. Dissolved Cu concentrations were preferred, as this measurement is the basis for both the hardness- and BLM-based Cu criteria, but total recoverable Cu concentrations were also retained in lieu of dissolved concentrations. The data were further filtered to remove any samples in which hardness, or calcium and magnesium ions, were not analyzed. The resulting dataset was then used to compare stream Cu concentrations to hardness-based Cu criteria. For the BLM-based evaluations the data had to be filtered further because all BLM parameters are not as routinely analyzed as is hardness. In addition to Ca and Mg, the required BLM parameters are: temperature, pH, DOC, sodium (Na), potassium (K), sulfate (SO_4), chloride (Cl), and alkalinity. This second dataset was used to calculate BLM-based criteria and olfactory BLM-based IC20 values for olfactory impairment following Meyer and Adams (2010). Non-detected Cu concentrations with detection limits exceeding Cu criteria were excluded from the analysis.

To further examine the Copper River case-in-point, since data for this waterbody were not available in either of the USGS databases, information from a State of Alaska Department of Natural Resources report (Maurer and Ray 1992) was utilized. The purpose of the study described in this report was to evaluate the impact of the Copper River Highway on surface water quality. The report included water quality data from 1992, as well as historical data dating back to 1951. Since data for the Copper River watershed are generally scarce, the historical information was also evaluated for comparative purposes.

Copper Criteria Calculations

The State of Alaska's current acute and chronic freshwater Cu criteria are calculated as follows (ADEC 2008):

$$\text{Acute Cu Criterion, } \mu g/L = e^{(0.9422 \times \ln(\text{Hardness, mg/L}) - 1.700)} \times 0.96 \quad (1)$$

$$\text{Chronic Cu Criterion, } \mu g/L = e^{(0.8545 \times \ln(\text{Hardness, mg/L}) - 1.702)} \times 0.96 \quad (2)$$

The USEPA's BLM-based acute and chronic criteria were calculated using *The Biotic Ligand Model Windows Interface, Version 2.2.1: User's Guide and Reference Manual, HydroQual, Inc, Mahwah, NJ, February 2007*, which can be downloaded from http://www.epa.gov/waterscience/criteria/copper/2007/index.htm.

Finally, the olfactory BLM-based IC20 values for olfactory impairment, as parameterized in Meyer and Adams (2010), were derived by changing the sensitivity parameter in the current BLM used by the USEPA. Version 2.2.3 of HydroQual's Cu BLM was used, as this version is necessary to change the sensitivity parameter (http://www.hydroqual.com/wr_blm.html). The version available for download from the USEPA only allows for calculation of criteria concentrations. Following Meyer and Adams (2010), the critical Cu accumulation concentration in the BLM parameter file ('Cu_Rainbow_Trout_06-10-07.DAT') was changed to 0.1988 nmol/g wet wt. The resulting output is the dissolved Cu concentration resulting in 50% inhibition (i.e., IC50 concentration) of the olfactory response in rainbow trout. To estimate a low effect level, Meyer and Adams (2010) derived IC20 values based on concentration-response relationships from McIntyre et al. (2008a,b). The IC20 was estimated as 0.315 × IC50 (see Meyer and Adams [2010] for details).

Hardness-based criteria were calculated for all USGS data, as well as for the Copper River watershed (Maurer and Ray 1992). BLM-based criteria and olfactory-based IC20 values were calculated for USGS data when the BLM-required data were available (e.g., DOC, pH, alkalinity). Insufficient water chemistry data are available to run the BLM for the Copper River watershed.

Salmon Population Data

Salmon population data were researched for those stream locations where Cu concentrations exceeded Cu criteria. Information was gathered from the Alaska Department of Fish and Game (ADF&G) website (ADF&G 2011a).

First, the site of each stream location was determined relative to the various management regions and areas used by ADF&G to evaluate the salmon fisheries. Second, ADF&G's Geographic Information Systems (GIS) interactive maps (available in the "Lands and Waters" section of ADF&G's website; [ADF&G 2011b]) were queried to determine whether the streams associated with each location were: 1) considered passable by fish (i.e., culvert classification data), 2) routinely surveyed by ADF&G (i.e., fish survey data), and 3) known to support anadromous fish (i.e., anadromous water catalogue). Among the data available from ADF&G, these maps had the finest spatial resolution; however, information regarding population status could not be ascertained from these maps. Therefore, GIS data were mostly used to determine whether salmon had the potential to be present at each of the stream locations. Lastly, for the ADF&G management area and/or region associated with each stream location, the most recent salmon fishery review and forecast documents were evaluated to gain an understanding of the current status of salmon returns relative to both years past as well as the predicted future. These documents (located within the Commercial Salmon Fisheries sections of the Management Area portions of ADF&G's Commercial Fisheries website) often did not contain information germane to the specific stream locations in question, but were reviewed for salmon population data at as fine a spatial scale as possible (i.e., either management Region [largest scale], Area, District, Sub-district [smallest scale], etc.).

RESULTS

Comparison of Copper Concentrations to Criteria

The streams/sites where the Cu concentration in at least one sample exceeded BLM- or hardness-based Cu criteria are summarized in Tables 1 and 2, respectively. The ratios of the Cu concentrations to criteria are expressed as hazard quotients (HQs). The mean HQ for each stream location is also provided. The criteria exceedances based on total recoverable Cu concentrations are conservative, but the streams from which the samples were collected were retained for this analysis. The number of stream locations with mean Cu HQs, either acute or chronic, exceeding 1.0 were limited to: (1) Hue Creek (within/below Hue Shale outcrop near Kaktovikak); (2) Kenai River (below Skilak Lake outlet near Sterling); (3) Johnson River (above Lateral Glacier near Tuxedni Bay); (4) Moose Creek (above Wishbone Hill near Sutton); (5) Cannery Creek (near Juneau); (6) Gold Creek (near Juneau); (7) Peterson Creek (below north fork near Auke Bay); and (8) Tributary to Zinc Creek (near Juneau). All other stream locations shown in Tables 1 and 2 generally only had a single sample with Cu HQs exceeding one and mean HQs were well below one. Thus, the eight stream locations mentioned above were the focus of this evaluation.

In addition, based on the data collected by Maurer and Ray (1992) as well as the historical data presented in their report, the Copper River also had hardness-based criteria exceedances for some locations and tributaries (Table 3). Thus, salmon population data were queried for this waterbody as well.

With one exception, none of the stream samples had a Cu concentration greater than the predicted olfactory-based IC20 value. The one exception was Hue Creek, which had a dissolved

Cu concentration of 4 µg/L and the predicted olfactory-based IC20 value was 3.9 µg/L, so essentially equivalent (an HQ of 1.02). Overall, therefore, the Alaska streams, for which Cu data are available, do not have Cu concentrations exceeding predicted olfactory-based toxicity thresholds for salmon.

Evaluation of Salmon Population data

For the aforementioned eight stream locations, plus the Copper River, salmon populations were evaluated by querying information provided by ADF&G as described above. Summaries of available information related to the salmon fishery in each of these areas are below.

(1) ***Hue Creek (within/below Hue Shale outcrop near Kaktovik)*****:** This stream location had both acute and chronic BLM-based criteria exceedances in two of three samples, based on data collected in 1996 (Table 1). The mean acute HQ was 3.3 (range of 0.6 – 8.4), and the mean chronic HQ was 5.4 (range of 0.9 – 13.5). Hue Creek is a tributary to Ignek Creek, which drains into the Canning River, and is located within the Northern management area of ADF&G's Arctic-Yukon-Kuskokwim (AYK) commercial fishery management region. Notably, Hue Creek is located within the Arctic National Wildlife Refuge.

There are no commercial fisheries for salmon species in the Northern Management Area (Bue et al. 2001), and so fish surveys have not been conducted (as indicated on ADF&G's interactive maps [ADF&G 2011b]). Relatedly, culvert classification data, which describe whether a water body is adequate for fish passage, are also not available for many waters of this area. However, according to the AYK Northern Management Area Commercial Fisheries Overview (ADF&G 2011c), as well as the most recent Annual Management Report for the Northern Management Area (Bue et al. 2011), subsistence fisheries are known to exist along the Arctic coast in which smaller numbers of chum, pink, and Chinook salmon are harvested, though Arctic cisco, broad whitefish, Dolly Varden, and Arctic grayling are believed to be the more commonly harvested fish of these subsistence fisheries.

(2) ***Kenai River (below Skilak Lake outlet near Sterling)*****:** This stream location also had both acute and chronic BLM-based criteria exceedances (n = 1), based on data collected in 1999 (Table 1). The only sample evaluated had an acute HQ of 2.5 and a chronic HQ of 4.1. The Kenai River is located within the Upper Cook Inlet (UCI) management area of ADF&G's Central commercial fishery management region. This Central region boasts some of the largest and most valuable salmon fisheries in the world and all five species of Pacific salmon are subject to commercial harvest in the UCI (ADF&G 2011d). In fact, based on information collected as far back as 1966, on average, five percent of the total statewide salmon catch comes from the UCI (Shields 2010).

This Kenai River location is specifically situated in the Central district of the UCI, where both set and drift gillnets are used for salmon harvest (Shields 2010). According to ADFG interactive maps, few culverts along the Kenai River are considered inadequate for supporting passage of anadromous fish, so it is reasonable to assume salmon are present at this stream location. The Kenai River fishery in general has expanded significantly in recent years, now supporting the largest sport and recreational fishery for both sockeye salmon and Chinook salmon in Alaska (ADF&G 2011e). In particular, the Kenai River is the largest producer of sockeye salmon in the UCI (Eggers and Carrol

2011). Additionally, in 2010, the forecasted sockeye salmon run to the Kenai River was 1.7 million, but was actually recorded at 3.3 million (Eggers and Carroll 2011). The 2011 UCI Sockeye Salmon Forecast estimates a 3.9 million run this year, which is nine percent greater than the 20-year average for this fishery (Eggers and Carroll 2011).

(3) ***Johnson River (above Lateral Glacier near Tuxedni Bay)*****:** Based on data collected in 1999 and 2001, this stream location had both acute and chronic BLM-based criteria exceedances in three of five samples, and chronic-only BLM-based criteria exceedances in the remaining two samples (Table 1). The mean acute HQ was 1.6 (range of 0.9 – 3.5), and the mean chronic HQ was 2.5 (range of 1.3 – 5.7). The Johnson River is located within the Lower Cook Inlet (LCI) management area of ADF&G's Central commercial fishery management region. As previously mentioned, the Central region boasts some of the largest and most valuable salmon fisheries in the world (ADF&G 2011d). Though all five species of Pacific salmon are present in the LCI, pink salmon tend to dominate the freshwater drainages within the area (ADF&G 2011f). In addition, fisheries enhancement (i.e., stocking streams with hatchery fish) is a significant contributor to LCI salmon production, at times supplying up to 90 percent of the harvest (ADF&G 2011f).

Anadromous fish are known to occur in the Johnson River and have been identified in fish inventory reports (ADF&G 2011g). Specifically, according to ADF&G's interactive maps (ADF&G 2011b), chum and pink salmon have been identified in the Johnson River. Descriptions of trends and characteristics of the fishery in the Johnson River were not available; however, information pertaining to the LCI suggests total commercial salmon harvests fell well below 10- and 20-year averages in 2010, with less than half of the pre-season projected total of 1.02 million (Eggers and Carroll 2011). This decline is likely the result of the shutdown/inactivity of several local hatcheries which, as previously mentioned, are a substantial contributor to the salmon fishery in the LCI (ADF&G 2011f). Runs of naturally produced salmon were somewhat weak, but still generally met or exceeded sustainable escapement goals (SEG) throughout the LCI (ADF&G 2011f).

(4) ***Moose Creek (above Wishbone Hill near Sutton)*****:** Only chronic BLM-based criteria exceedances were observed at this stream location (i.e., in two of four samples), based on data collected in 1999 – 2001 (Table 1). The mean chronic HQ was equal to 1.1 (range of 0.4 – 1.6). Like the Kenai River stream location, Moose Creek is also located within the UCI management area of ADF&G's Central commercial fishery management region, but this stream location is specifically situated in the Northern District of the UCI, where only set gillnets are permitted (Shields 2010).

Interactive maps indicate that anadromous fish species, including coho salmon and Chinook salmon, inhabit this creek (ADF&G 2011b), though there are portions of Moose Creek (i.e., four locations downstream of Wishbone Hill, closer to Baxter Mine) where ADF&G has classified conditions as impassable or potentially impassable by fish (ADF&G 2011b). Fish surveys are carried out on Moose Creek and have reported catches of Dolly Varden, coho salmon, slimy sculpin, and rainbow trout (ADF&G 2011b). Descriptions of general trends and characteristics of the fishery in Moose Creek were not available. However, information pertaining to the Northern District of the UCI suggests that, although some fishery restrictions have been put in place to protect species from other areas, coho stocks are in good condition. However, Northern District Chinook stocks are being considered for 'stock of management concern' status (Shields

2010). Concerns regarding Northern District Chinook salmon were first raised in 1986 and conditions have not shown consistent improvement since; thus, the future of this fishery is unknown (Shields 2010).

(5) ***Cannery Creek (near Juneau), (6) Gold Creek (near Juneau), (7) Peterson Creek (Near Auke Bay, below North Fork)*, and (8) *Tributary to Zinc Creek (Near Juneau)*:** These stream locations all had both acute and chronic hardness-based criteria exceedances except Gold Creek, in which only acute criteria were exceeded. Mean acute and chronic HQs (and range and number of samples where criteria were exceeded/total number of samples available) were as follows (Table 2): Cannery Creek – mean acute HQ of 8.1 (8.1 – 8.1, 1/1), mean chronic HQ of 10.9 (10.9 – 10.9, 1/1); Peterson Creek – mean acute HQ of 1.4 (1.0 – 1.7, 1/2), mean chronic HQ of 1.8 (1.3 – 2.2, 2/2); Tributary to Zinc Creek – mean acute HQ of 1.3 (1.3 – 1.3, 1/1), mean chronic HQ of 1.7 (1.7 – 1.7, 1/1); Gold Creek – mean chronic HQ of 1.2 (0.1 – 2.7, 5/7). Each of these creeks are all located within the Juneau management district of ADF&G's Southeastern commercial fishery management region.

ADF&Gs interactive maps indicate that Gold Creek is an anadromous stream in which chum salmon and pink salmon have been found (though information is only available from one location on the lower part of the Creek, close to Government Dock on Gausteneau Channel). Peterson Creek is also an active anadromous waterway, where species such as coho and pink salmon, cutthroat trout, and Dolly Varden are known to occur. These maps do not indicate there are any data available for Cannery Creek or Tributary to Zinc Creek; however, unnamed waterbodies south of these two waterways do support anadromous fish including Dolly Varden, and chum, coho, and pink salmon.

Descriptions of general trends and characteristics of the fishery were not available for any of these stream locations. However, the 2010 commercial fish harvest of the Southeast region was below the 10-year average harvest of 54.7 million and just below the long-term average harvest since 1962 of 38.6 million (Eggers and Carroll 2011), though this was a marked improvement over 2009 returns.

(9) ***Copper River*:** Copper River locations and tributaries had both acute and chronic hardness-based criteria exceedances. Recall, BLM-based criteria could not be calculated for these data since key model parameters were not available. Data collected by Maurer and Ray (1992) resulted in both acute and chronic exceedances at three of the 13 sites sampled and one site had chronic-only HQs greater than one. Historical data presented in Maurer and Ray's (1992) report also resulted in both acute and chronic HQs greater than one (based on mean concentrations) at two of the four locations sampled. The Copper River is located in the Southcentral commercial fishery management region and represents its own Copper River Management area (ADF&G 2011g).

The Copper River supports commercial, sport, and personal use fisheries and maintains populations of all five Pacific salmon species. The sockeye and Chinook salmon runs that have been commercially fished since the late 1800s are among the earliest and most prized in the state (ADF&G 2011g). In fact, ADF&G only prepares forecasts for salmon runs that affect major fisheries around the state, and Copper River sockeye and Chinook salmon are among that list of forecasted runs (Eggers and Carroll 2011). In addition to the commercial fishery, three species of North Pacific salmon (Chinook, coho, and sockeye) are available to anglers fishing upper Copper River drainage waters.

Furthermore, a resident-only, personal use dipnet fishery as well as a subsistence fishery takes place in the mainstem of the Copper River. The 2010 commercial harvests for sockeye, Chinook, and coho were each well below their 10-year average harvests, and approximately 35 percent of the commercially harvested sockeye salmon are believed to have originated from area hatchery stocking (Eggers and Carroll 2011).

DISCUSSION

Overall, given the spatial and temporal variability in the Cu concentration data relative to the salmon population data, correlations between the two are tenuous. The salmon population data were typically available at a much larger spatial scale with trends expressed over several years (or decades), while Cu concentration data were often only available for a select location on a stream and for a limited number of years. In addition, very few Alaskan streams had Cu concentrations exceeding criteria. Of the 453 samples compiled for this evaluation with sufficient information to derive BLM-based Cu criteria, only 19 samples had at least one Cu concentration exceeding the acute criterion (4%, nine streams) and 33 samples had at least one Cu concentration exceeding the chronic criterion (7%, 11 streams). A similar pattern was observed for the hardness-based Cu criteria. Accordingly, there were limited opportunities to co-locate streams with Cu criteria exceedances with salmon population data. Additionally, the influence of harvest rates and hatchery stocking rates, which vary between years, further compounds the uncertainties in this evaluation. However, Cu criteria exceedances were so infrequent, and negligible in magnitude, that any reductions in a salmon fishery for a given region would almost certainly be attributed to other factors (e.g., harvest rates, hatchery production). The potential contribution of Cu to any decline is clearly uncertain.

However, despite the uncertainties, there is no evidence to suggest that existing Cu criteria, whether BLM-based or hardness-based, are under-protective of salmon. For example, at Hue Creek, located within the Arctic National Wildlife Refuge (ANWR), there are no fish surveys available, but the larger management area that comprises Hue Creek is known to support subsistence fisheries of several salmon species. In fact, exceedance of a BLM-based Cu criterion at a stream site within ANWR seems to support that the criterion is not under-conservative and may actually be over-conservative. Similarly, the Kenai River, which had a Cu concentration from a single sample collected near Sterling in 1999 exceeding the acute Cu criterion, supports a significant salmon fishery, with sockeye salmon returns exceeding forecasts in recent years. These types of observations, along with the finding that Cu concentrations throughout the state are less than predicted olfactory-based IC20 values for salmon, suggest that existing streams with Cu concentrations meeting Cu criteria are protective of salmon, with some examples suggesting that certain streams can tolerate Cu concentrations that moderately exceed criteria, at least at times, without any clear effect on salmon populations.

Finally, although Cu concentrations in the Copper River, famous for the strength of its salmon runs, may not be as high as sometimes perceived, the Copper River still provides support that existing Cu criteria are protective of salmon and do not need to be lowered. For example, long-term historical Cu concentrations in the main stem of the Copper River ranged from <1 to 23 µg/L from the 1950s through 1991, with certain tributaries similarly having Cu concentrations of approximately 10 µg/L. Given that the hardness of the main stem of the Copper River ranges from moderately-hard to hard, these Cu concentrations appear to variably be near associated hardness-based Cu criteria (i.e., sometimes below and sometimes above). This again provides some support that the existing Cu criteria are at least protective against effects on salmon.

Although the field-based evaluation described here consists of several uncertainties, no data were identified that clearly refute the conclusion from Meyer and Adams (2010) that existing Cu criteria are protective against olfactory impairment in salmon.

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Table 1. Alaska streams with dissolved or total recoverable Cu concentrations exceeding BLM-based criteria.

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	DOC (mg/L)	pH	Acute BLM-based Criteria (µg/L)	Chronic BLM-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
Hue Cr.	8/1/1996	4	-	176	0.3	6.7	0.5	0.3	8.4	13.5	3.3	5.4
(within/below Hue Shale outcrop near	8/2/1996	2	-	259	0.4	7.5	1.9	1.2	1.0	1.7		
Kaktovik)	8/2/1996	1	-	246	0.4	7.4	1.7	1.1	0.6	0.9		
Kenai R. (below Skilak L. outlet near Sterling)	6/2/1999	-	1.473	*24.8*	0.4	6.9	0.6	0.4	2.5	4.1	2.5	4.1
Johnson R.	5/17/1999	2.1	-	27.5	0.3	7.1	0.6	0.4	3.5	5.7	1.6	2.5
(above Lateral Glacier near Tuxedni Bay)	5/23/2001	0.6	-	38.7	0.2 E	7.2	0.5	0.3	1.3	2.1		
	6/26/2001	0.6	<20	18.4	0.2 E	7.2	0.5	0.3	1.3	2.1		
	8/1/2001	0.5	<20	15.2	<0.3	7.1	0.6	0.4	0.8	1.3		
	9/27/2001	0.4	<20	24.7	<0.3	6.9	0.4	0.3	0.9	1.5		
Moose Cr.	6/29/1999	-	1.5	26.8	0.4	7.6	1.5	0.9	1.0	1.6	0.7	1.1
(above Wishbone Hill near Sutton)	11/12/1999	-	1 E	40.7	0.7	7.4	2.1	1.3	0.5	0.8		
	4/5/2000	-	0.6 E	49	0.5	7.7	2.2	1.4	0.3	0.4		
	6/19/2001	-	1.2	21.5	0.6	7.1	1.2	0.7	1.0	1.6		
Moose Cr. (near Palmer)	3/18/1999	-	1	56.4	0.5	7.5	1.8	1.1	0.5	0.9	0.5	0.8
	11/12/1999	-	1.6	52.8	1.6	7.8	8.0	5.0	0.2	0.3		
	4/5/2000	-	0.6 E	55.1	0.8	7.6	3.2	2.0	0.2	0.3		
	6/28/2000	-	2.9 E	24.9	0.5	7.8	2.4	1.5	1.2	1.9		
	6/19/2001	-	1.9	24.1	0.9	7.8	4.3	2.7	0.4	0.7		
	10/12/2001	-	1 E	44.6	0.9	7.7	3.9	2.4	0.3	0.4		
El Dorado Cr.	6/13/2008	8.5	-	224	5.0	8.1	36.2	22.5	0.2	0.4	0.5	0.8
(0.5 mi above mouth, near Kantishna)	7/14/2008	6.3	-	254	2.5	8.0	17.8	11.0	0.4	0.6		
	9/9/2008	7.3	-	243	1.3	8.2	10.9	6.8	0.7	1.1		
	7/12/2010	3.1	-	268	2.6	8.2	23.1	14.4	0.1	0.2		
	9/6/2010	11.8	-	248	1.4	8.1	11.5	7.2	1.0	1.6		
Hobo Cr.	10/25/2005	0.24 E	0.3 E	2.97	7.0	5.9	1.7	1.1	0.1	0.2	0.4	0.7
(near Petersburg)	1/31/2006	0.7	0.4 E	4.69	4.3	6.0	1.0	0.6	0.7	1.1		
Slate Cr. (2.1 mi above El Dorado Cr. Near	6/12/2008	1.4	-	101	3.0	6.5	2.5	1.6	0.6	0.9	0.4	0.6
Kantishna)	7/13/2008	1.5	-	141	2.2	6.7	2.8	1.8	0.5	0.8		
	9/11/2008	1.0	-	168	1.6	6.7	2.2	1.4	0.4	0.7		
	6/2/2009	0.98 E	-	137	3.1	7.2	8.2	5.1	0.1	0.2		

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	DOC (mg/L)	pH	Acute BLM-based Criteria (µg/L)	Chronic BLM-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
	7/28/2009	1.0	-	163	1.5	6.6	1.8	1.1	0.6	0.9		
	9/9/2009	1.5	-	164	1.7	6.6	2.0	1.3	0.7	1.2		
	6/1/2010	1.9	-	162	6.7	7.1	16.0	9.9	0.1	0.2		
	7/13/2010	2.0	-	124	2.7	7.3	8.0	5.0	0.2	0.4		
	9/7/2010	2.0	-	173	1.6	7.5	6.6	4.1	0.3	0.5		

Table 2. Alaska streams with dissolved or total recoverable Cu concentrations exceeding hardness-based criteria.

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
Cannery Cr. (near Juneau)	9/4/1990	33	35	28.1	4.1	3.0	8.1	10.9	8.1	10.9
Peterson Cr. (below north fork near Auke Bay)	1/17/2002	5 E	-	19.8	2.9	2.2	1.7	2.2	1.4	1.8
	6/12/2001	3 E	-	20.2	3.0	2.3	1.0	1.3		
Trib. To Zinc Cr. (near Juneau)	7/16/1991	7	7	39.1	5.5	4.0	1.3	1.7	1.3	1.7
Gold Cr. (near Juneau)	7/15/2004	8	-	27.3	4.0	3.0	2.0	2.7	0.9	1.2
	5/18/1990	10	-	56.1	7.8	5.5	1.3	1.8		
	1/30/1991	10	-	82.3	11.2	7.6	0.9	1.3		
	8/2/2004	5	-	42.4	6.0	4.3	0.8	1.2		
	9/30/2002	6 E	-	54.6	7.6	5.3	0.8	1.1		
	11/17/2004	1 E	-	60.4	8.4	5.8	0.1	0.2		
	2/15/2006	1 E	-	85.3	11.6	7.8	0.1	0.1		
Crooked Cr. (above Airport Rd.)	5/12/2010	7	-	26.9	3.9	2.9	1.8	2.4	0.3	0.4
	5/8/2008	1.5	-	18	2.7	2.1	0.6	0.7		
	5/1/2009	1.3	-	19.7	2.9	2.2	0.4	0.6		
	7/1/2008	2.1	-	47.1	6.6	4.7	0.3	0.4		
	9/6/2007	1.3	-	69.6	9.6	6.6	0.1	0.2		
	6/25/2010	1.2	-	69.7	9.6	6.6	0.1	0.2		
	10/14/2009	1.2	-	81.5	11.1	7.5	0.1	0.2		
	10/12/2007	0.99	-	72.2	9.9	6.8	0.1	0.1		
	8/9/2007	0.81	-	72.8	10.0	6.8	0.1	0.1		
	9/3/2010	0.75	-	78.2	10.7	7.3	0.1	0.1		
	7/2/2009	0.64	-	79.8	10.9	7.4	0.1	0.1		
Yukon R. (at Pilot Station)	6/6/1990	15	-	71.5	9.8	6.7	1.5	2.2	0.3	0.4
	8/29/1996	11	-	103	13.8	9.2	0.8	1.2		
	5/17/2005	6	-	73.2	10.0	6.9	0.6	0.9		
	8/29/1996	8	-	103	13.8	9.2	0.6	0.9		
	7/25/1996	7	-	88.1	11.9	8.0	0.6	0.9		
	7/11/1991	7	-	102	13.7	9.1	0.5	0.8		
	5/26/2004	5.4	-	75.3	10.3	7.0	0.5	0.8		
	6/12/2002	5	-	73.2	10.0	6.9	0.5	0.7		

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
	6/1/2005	5.3	-	79.7	10.9	7.4	0.5	0.7		
	5/28/2003	4.5	-	80.5	11.0	7.4	0.4	0.6		
	6/17/2003	4.5	-	81.6	11.1	7.5	0.4	0.6		
	6/20/2002	3.3	-	78.9	10.7	7.3	0.3	0.5		
	6/15/2004	3.6	-	87.4	11.8	8.0	0.3	0.5		
	8/14/2001	3.9	-	98.6	13.3	8.8	0.3	0.4		
	9/5/1991	4	-	108	14.4	9.6	0.3	0.4		
	7/1/2002	3.3	-	93.1	12.6	8.4	0.3	0.4		
	7/5/2001	2.9	-	90.8	12.3	8.2	0.2	0.4		
	6/29/2004	2.9	-	93.5	12.6	8.5	0.2	0.3		
	6/14/2005	2.9	-	93.6	12.6	8.5	0.2	0.3		
	8/19/2003	3.1	-	103	13.8	9.2	0.2	0.3		
	9/25/1990	3	-	105	14.1	9.3	0.2	0.3		
	9/27/2005	3.1	-	110	14.7	9.7	0.2	0.3		
	7/16/2002	2.6	-	93.2	12.6	8.4	0.2	0.3		
	8/30/2001	2.8	-	103	13.8	9.2	0.2	0.3		
	9/23/2003	2.8	-	107	14.3	9.5	0.2	0.3		
	9/24/2002	2.7	-	109	14.6	9.6	0.2	0.3		
	7/25/2001	2.4	-	96	12.9	8.6	0.2	0.3		
	7/12/2005	2.6	-	108	14.4	9.6	0.2	0.3		
	7/24/2003	2.5	-	107	14.3	9.5	0.2	0.3		
	9/21/2001	2.3	-	111	14.8	9.8	0.2	0.2		
	8/8/2002	2.1	-	106	14.2	9.4	0.1	0.2		
	8/16/2005	2.4	-	124	16.5	10.8	0.1	0.2		
	8/18/2004	1.9	-	118	15.7	10.3	0.1	0.2		
	7/20/2004	1.8	-	112	15.0	9.9	0.1	0.2		
	4/12/1991	2	-	144	18.9	12.2	0.1	0.2		
	9/22/2004	1.3	-	136	18.0	11.6	0.1	0.1		
	3/17/2005	1.4	-	168	21.9	14.0	0.1	0.1		
	4/7/2004	1.2	-	169	22.0	14.0	0.1	0.1		
	4/19/2001	1	-	162	21.2	13.5	0.0	0.1		
	3/25/2003	0.9	-	153	20.1	12.9	0.0	0.1		
	4/2/2002	0.8	-	156	20.4	13.1	0.0	0.1		

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
Yukon R. (near Stevens Village)	6/2/2005	5.1	-	36.3	5.2	3.8	1.0	1.4	0.2	0.3
	5/13/2005	5.7	-	85.9	11.6	7.9	0.5	0.7		
	6/2/2001	4.4	-	65.6	9.0	6.2	0.5	0.7		
	5/23/2005	4.8	-	79.9	10.9	7.4	0.4	0.6		
	6/4/2004	3.6	-	85.3	11.6	7.8	0.3	0.5		
	6/4/2002	3.3	-	83.6	11.4	7.7	0.3	0.4		
	5/29/2003	3.4	-	89.4	12.1	8.1	0.3	0.4		
	6/18/2001	2.9	-	88.7	12.0	8.1	0.2	0.4		
	6/9/2004	2.8	-	85.6	11.6	7.8	0.2	0.4		
	7/13/2001	2.8	-	97.6	13.1	8.8	0.2	0.3		
	6/12/2003	2.5	-	93.7	12.6	8.5	0.2	0.3		
	8/22/2005	2.9	-	118	15.7	10.3	0.2	0.3		
	10/2/2000	2.6	-	104	13.9	9.3	0.2	0.3		
	6/24/2002	2.3	-	98.7	13.3	8.9	0.2	0.3		
	9/10/2004	2.7	-	122	16.2	10.6	0.2	0.3		
	9/4/2002	2.4	-	107	14.3	9.5	0.2	0.3		
	8/23/2002	2.3	-	102	13.7	9.1	0.2	0.3		
	7/18/2002	2.2	-	100	13.4	9.0	0.2	0.2		
	7/24/2003	2.2	-	110	14.7	9.7	0.1	0.2		
	7/15/2003	2.2	-	112	15.0	9.9	0.1	0.2		
	6/23/2004	2	-	105	14.1	9.3	0.1	0.2		
	8/14/2001	2	-	109	14.6	9.6	0.1	0.2		
	9/21/2001	2	-	109	14.6	9.6	0.1	0.2		
	9/11/2003	1.9	-	104	13.9	9.3	0.1	0.2		
	8/1/2005	2.1	-	117	15.6	10.2	0.1	0.2		
	8/21/2003	2	-	113	15.1	9.9	0.1	0.2		
	7/6/2005	1.8	-	119	15.8	10.4	0.1	0.2		
	7/30/2002	1.6	-	115	15.3	10.1	0.1	0.2		
	8/17/2004	1.5	-	114	15.2	10.0	0.1	0.1		
	7/13/2004	1.4	-	107	14.3	9.5	0.1	0.1		
	3/19/2002	1.3	-	129	17.1	11.1	0.1	0.1		
	3/26/2003	1	-	147	19.3	12.4	0.1	0.1		
	3/21/2001	0.8	-	147	19.3	12.4	0.0	0.1		

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
	4/1/2004	0.8	-	159	20.8	13.3	0.0	0.1		
	3/30/2005	0.7	-	151	19.8	12.7	0.0	0.1		
Kuskokwim R. (at Crooked Creek)	5/17/1991	9	-	49.5	6.9	4.9	1.3	1.8	0.3	0.4
	7/16/1991	6	-	105	14.1	9.3	0.4	0.6		
	9/24/1990	4	-	91.5	12.4	8.3	0.3	0.5		
	8/2/1990	4	-	107	14.3	9.5	0.3	0.4		
	6/7/1990	1	-	65.7	9.0	6.3	0.1	0.2		
	6/24/2010	0.96 E	-	94.7	12.8	8.5	0.1	0.1		
	4/11/1991	1	-	108	14.4	9.6	0.1	0.1		
	6/24/2010	0.79 E	-	93.5	12.6	8.5	0.1	0.1		
	9/2/2010	0.84 E	-	102	13.7	9.1	0.1	0.1		
	9/2/2010	0.83 E	-	104	13.9	9.3	0.1	0.1		
Stikine R. (near Wrangell)	5/23/1990	6	-	47.4	6.7	4.7	0.9	1.3	0.5	0.7
	5/23/1991	6	-	57.8	8.0	5.6	0.7	1.1		
	7/31/1990	3	-	39.6	5.6	4.1	0.5	0.7		
	7/31/1991	2	-	49.1	6.9	4.9	0.3	0.4		
	3/11/1991	2	-	102	13.7	9.1	0.1	0.2		
Montana Cr. (near Montana, AK)	9/23/2005	2	-	13.9	2.1	1.7	1.0	1.2	0.5	0.7
	3/30/2006	0.4 E	1.2	25	3.6	2.7	0.1	0.1		
Porcupine Cr. (near Fort Yukon)	8/26/2005	8.4	-	79	10.8	7.3	0.8	1.1	0.2	0.3
	5/19/2005	3.7	-	50.3	7.0	5.0	0.5	0.7		
	6/7/2004	4.3	-	62.1	8.6	6.0	0.5	0.7		
	5/25/2005	3.3	-	60.9	8.4	5.9	0.4	0.6		
	6/2/2004	2.5	-	53.9	7.5	5.3	0.3	0.5		
	6/18/2002	2.8	-	68.4	9.4	6.5	0.3	0.4		
	7/16/2001	2.8	-	77.8	10.6	7.2	0.3	0.4		
	6/26/2002	2.6	-	71.4	9.8	6.7	0.3	0.4		
	6/7/2005	2.5	-	69.5	9.5	6.6	0.3	0.4		
	9/17/2001	2.9	-	90	12.2	8.2	0.2	0.4		
	6/9/2003	2	-	60.1	8.3	5.8	0.2	0.3		
	6/30/2001	2.4	-	86.4	11.7	7.9	0.2	0.3		
	6/11/2004	2	-	69.8	9.6	6.6	0.2	0.3		
	7/23/2003	2.3	-	87.8	11.9	8.0	0.2	0.3		

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ	Mean Acute HQ	Mean Chronic HQ
	8/19/2003	2.3	-	93.9	12.7	8.5	0.2	0.3		
	6/6/2002	1.7	-	69.6	9.6	6.6	0.2	0.3		
	8/9/2004	2.2	-	107	14.3	9.5	0.2	0.2		
	8/26/2002	1.9	-	98.6	13.3	8.8	0.1	0.2		
	6/19/2003	1.8	-	92.7	12.5	8.4	0.1	0.2		
	8/7/2001	1.9	-	116	15.5	10.2	0.1	0.2		
	7/1/2003	1.7	-	106	14.2	9.4	0.1	0.2		
	9/27/2002	1.9	-	125	16.6	10.8	0.1	0.2		
	8/13/2002	1.6	-	105	14.1	9.3	0.1	0.2		
	8/27/2001	1.6	-	109	14.6	9.6	0.1	0.2		
	9/9/2004	1.7	-	139	18.3	11.9	0.1	0.1		
	9/22/2003	1.4	-	115	15.3	10.1	0.1	0.1		
	8/3/2005	1.5	-	131	17.3	11.3	0.1	0.1		
	7/14/2005	1.4	-	134	17.7	11.5	0.1	0.1		
	7/29/2004	1.4	-	162	21.2	13.5	0.1	0.1		
	4/6/2005	0.9	-	214	27.5	17.2	0.0	0.1		
	3/11/2002	0.8	-	198	25.6	16.1	0.0	0.0		
	3/29/2001	0.7	-	197	25.5	16.0	0.0	0.0		
	4/9/2004	0.7	-	210	27.0	16.9	0.0	0.0		
	4/4/2003	0.6	-	204	26.3	16.5	0.0	0.0		
Hobo Cr., East Fork (near Petersburg)	1/31/2006	0.7	0.4 E	4.69	0.8	0.7	0.9	1.1	0.7	0.8
	10/25/2005	0.24 E	0.3 E	2.97	0.5	0.4	0.5	0.5		
Moose Cr. (near Palmer)	6/28/2000	-	2.9 E	24.9	3.6	2.7	0.8	1.1	0.3	0.5
	6/19/2001	-	1.9	24.1	3.5	2.7	0.5	0.7		
	6/30/1998	-	2.1	29.4	4.2	3.1	0.5	0.7		
	11/12/1999	-	1.6	52.8	7.4	5.2	0.2	0.3		
	10/12/2001	-	1 E	44.6	6.3	4.5	0.2	0.2		
	3/18/1999	-	1	56.4	7.8	5.5	0.1	0.2		
	4/5/2000	-	0.6 E	55.1	7.7	5.4	0.1	0.1		

Table 3. Summary of data from Maurer and Ray (1992) and the historical data presented therein.

Stream	Sample Date	Diss. Cu (µg/L)	TR Cu (µg/L)	Hard-ness (mg/L)	Acute Hardness-based Criteria (µg/L)	Chronic Hardness-based Criteria (µg/L)	Acute HQ	Chronic HQ
Maurer and Ray (1992)								
Tiekel River	8/6/1992	10	-	28	4.1	3.1	2.4	3.3
Uranatina River	8/6/1992	10	-	31	4.5	3.3	2.2	3.0
Cleave Creek	8/6/1992	12	-	24	3.6	2.7	3.4	4.5
Nels Miller Slough	10/5/1992	<1	-	29	4.2	3.1	<0.2	<0.3
Upper Tasnusa River	8/6/1992	<1	-	21	3.1	2.4	<0.3	<0.4
Lower Tasnusa River	8/6/1992	<1	-	22	3.3	2.5	<0.3	<0.4
Lower Tasnusa River (field dup)	8/6/1992	<1	-	24	3.4	2.6	<0.3	<0.4
Nels Miller Slough	8/6/1992	<1	-	31	4.5	3.3	<0.2	<0.3
Upper Tasnusa River	10/5/1992	<1	-	35	5.0	3.7	<0.2	<0.3
Lower Tasnusa River	10/5/1992	<1	-	43	6.0	4.3	<0.2	<0.2
Cleave Creek	10/5/1992	6	-	55	7.7	5.4	0.8	1.1
Tiekel River	10/5/1992	<1	-	55	7.7	5.4	<0.1	<0.2
Uranatina River	10/5/1992	<1	-	53	7.5	5.2	<0.1	<0.2
Historical Data (all concentrations are averages)								
Tsina River above Stuart Creek near Tiekel	1970; 1972-73; 1975	10	-	61	8.4	5.9	1.2	1.7
Stuart Creek near Tiekel	1951-53; 1956; 1970; 1972-73	10	-	38	5.4	3.9	1.9	2.6
Copper River near Chitina	1951-58; 1963-72; 1974-75; 1978-89; 1991	5.3	-	79.9	10.9	7.4	0.5	0.7
Copper River near Chitina	1990-92	1.8	-	59	8.2	5.7	0.2	0.3

Geotechnical
Environmental
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January 6, 2012

Jim Powell
Department of Environmental Conservation
410 Willoughby Ave. Suite 303
P.O. Box 111800
Juneau, AK 99801-1800

Re: 2011 – 2013 Alaska Triennial Review: Recommendation to Incorporate the Biotic Ligand Model for Copper into Aquatic Life Criteria

Dear Mr. Powell:

Attached to this letter, please find our report providing comments as requested by the Alaska Department of Environmental Conservation (ADEC) for the current triennial review of surface water quality standards in Alaska. The undersigned represent members of a science team that has been working with the International Copper Association and Copper Development Association to conduct and implement scientific studies in support of regulating copper discharges to the aquatic environment.

We understand from ADEC documents posted announcing this triennial review that aquatic life criteria for copper are one of the two high priority issues for rulemaking. We hope you will find the attached documents helpful, and we believe they make a strong case for updating Alaska's freshwater copper criteria to reflect the most recent scientific and regulatory recommendations to base these criteria on the Biotic Ligand Model, rather than the existing hardness equations. In our view, the Biotic Ligand Model will not only provide the most scientifically accurate means of protecting aquatic life, but also is the best method for protecting against olfactory impairment in salmon -- a topic of growing concern over recent years.

Our submittal for the Triennial Review consists of the following report and supporting publications:

- Technical report: *Alaska Triennial Review: Recommendation to Incorporate the Biotic Ligand Model for Copper Into Aquatic Life Criteria.*
- DeForest, D.K., J.S. Meyer, R.W. Gensemer, B.K. Shepard, W.J. Adams, R.W. Dwyer, J.W. Gorsuch, and E.J. Van Genderen. 2010. Are ambient

GEI Consultants, Inc.
4601 DTC Boulevard, Suite 900, Denver, CO 80237
303.662.0100 fax: 303.662.8757

water quality criteria for copper protective of olfactory impairment? *Integrated Environmental Assessment and Management* 7(1):145-146.

- DeForest, D. K., R. W. Gensemer, E. J. Van Genderen, and J. W. Gorsuch. 2011. Protectiveness of water quality criteria for copper in western United States waters relative to predicted olfactory responses in juvenile Pacific salmon. *Integrated Environmental Assessment and Management* 7(3):336-347.
- Meyer, J. S., and W.J. Adams. 2010. Relationship between Biotic Ligand Model-based water quality criteria and avoidance and olfactory responses. *Environmental Toxicology and Chemistry* 20:2096-2103.

We appreciate the opportunity to provide you these comments. Please feel free to contact Robert Gensemer if you have any questions. We look forward to discussing our recommendations with you.

Sincerely,

Robert W. Gensemer, Ph.D.
Vice President
303-264-1030
bgensemer@geiconsultants.com

William Adams, Ph.D.
General Manager
Rio Tinto

David DeForest
Environmental Toxicologist
Windward Environmental

Robert Dwyer, Ph.D.
Associate Director – Environment
International Copper Association, Ltd.

Joseph Gorsuch
Manager, Health & Environmental Sciences
Copper Development Association

Joseph Meyer, Ph.D.
Retired Professor
University of Wyoming

Robert Santore
Professional Associate
HDR Inc.

RWG
cc: Stephanie Baker, GEI
Steven Canton, GEI